ACTUAL EROSION BY RIVERS IN THE BOLIVIAN ANDES

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INTRODUCTION

In Bolivia, the Andean Mountain belt is very large and deformed by thin-skinned tectonics (Baby et al., 1997). The back arc orogenic wedge is formed by the Cordillera Oriental – which limits the Altiplano enigmatic high plateau (Rochat et al., 1999) - and the Subandean zone, and characterized by an elbow shape of the mountain range (Bolivian orocline) and high relief (several summits over 6000 m). It over thrusts and supplies its adjacent foreland sedimentary basin with sediments since upper Oligocene times. The present axis of the Bolivian orocline separates the High Amazonian drainage basin in the north from the Pilcomayo drainage basin in the south. Little data is available to measure the actual erosion of the Andes cordillera. However, the measurement of sedimentary yields at the hydrological stations makes it possible to estimate these actual rates of erosion and their geographical variability.

DATA AND METHODS

In the Andes of Bolivia, the data obtained at the hydrological networks of various national services (ENDE, SENAMHI, SEARPI) made it possible to select 42 gauge stations (Figure 1) including 23 on the Amazon River basin, 13 on the basin of the Paraguay River and 5 on the endoreic Altiplano basin. In spite of different observation times and durations, the great quantity of samples collected on the Andean rivers (28 167) allows a realistic estimate of sedimentary flows. With extreme altitudes of 170 m (station of piedmont) to 6400 m (tops of the Real Cordillera), the studied basins show very contrasted characteristics, with mean basin altitude varying from 1175 to 4925 m (Guyot et al., 1990, 1996). The selected hydrological stations drain nested basins, of variable area (from 160 to 81 300 km^2) and slope (from 7 to 37%). Basin area extraction followed the methodology described in Seyler et al. (in press). The GTOPO30 DEM, river network extracted from JERS 1 mosaic (TRFIC project) , digitalized maps, and D8 algorithm were used. The flow accumulation threshold has been chosen as the minimum area necessary to delineate the streams gauged. For each delineated basin, the slope has been calculated, and used in the statistical exploration. Processing involved Arc-View, Erdas Imagine, and avenue scripts developed by the University of Texas at Austin (Maidment et al., 1997).

These basins, distributed on the whole of the Andean domain of Bolivia, are subjected to very contrasted climates: of 350 mm/yr in the arid regions of the altiplano, with more 3800 mm/yr in the Andean piedmonts of the Amazonian basin, and present runoff coefficients from 10 to 72% (Roche et al., 1992). The lithological index was calculated by using the Probst indices. The lithology of each basin was extracted from the geological map of Bolivia by using a SIG. The forest cover index (from to 0 to 100% depending of the sub-basin) was also extracted with the SIG from the Bolivian chart of vegetation.

RESULTS

The results obtained show a very strong heterogeneity, with suspended sediment concentrations varying from 46 to 19600 mg.l^{-1} during the hydrological cycle, and a rate of current erosion varying from 21 to 18200 t.km^{-2}.yr^{-1} according to the basins (Guyot et al., 1990, 1996). Using a forward stepwise multiple regression analysis with the whole dataset, the significant control variables are only drainage area and slope, with a multiple regression coefficient r=0.53. The same trend was observed with a smallest dataset not including the Altiplano Rivers (Aalto et al., in press).

Using the same forward stepwise multiple regression analysis, but separating in different geographical groups, the multiple regression coefficients present better values, and it becomes possible to calculate a rate of erosion for each sub basins (Figure 2). For the Altiplano basin rivers (r=1.00), the control factors are drainage area, slope and rainfall. For the Pilcomayo basin rivers (r=0.98), the control factors are also drainage area, runoff and lithologic index. In the Amazon basin, erosion rates in the Beni (r=0.96) and Chapare (r=0.99) basins are controlled by rainfall and runoff, whereas in the Grande (r=0.97) basins, these erosion rates depend of lithologic index and forest cover.

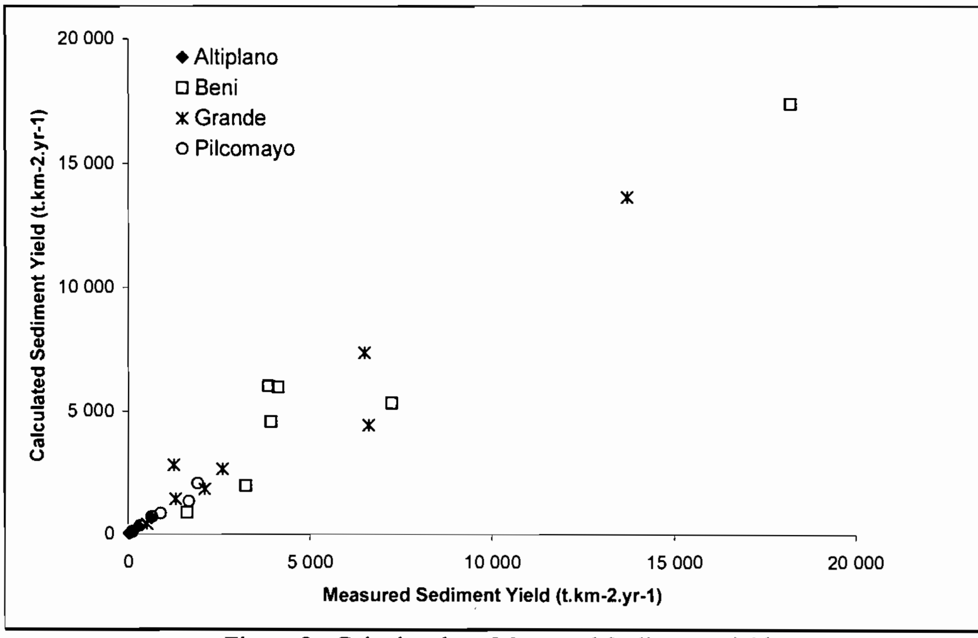

Figure 2 : Calculated vs. Measured Sediment Yield

For each geographical group, the largest basin corresponds either to the Andean piedmont (Angosto del Bala for the Beni river, Abapo for the Grande river, Villamontes for the Pilcomayo river), or to the station of Ulloma on Altiplano. The compared hypsometry of these four basins show different stages of evolution (Fig. 3). The Altiplano basin presents a more advanced stable profile, with erosion stopped by the regional endoreism. The Beni, Grande and Pilcomayo basins correspond to different levels of erosion, with a positive gradient from South towards North: profile of Beni River being more advanced than that of Pilcomayo.

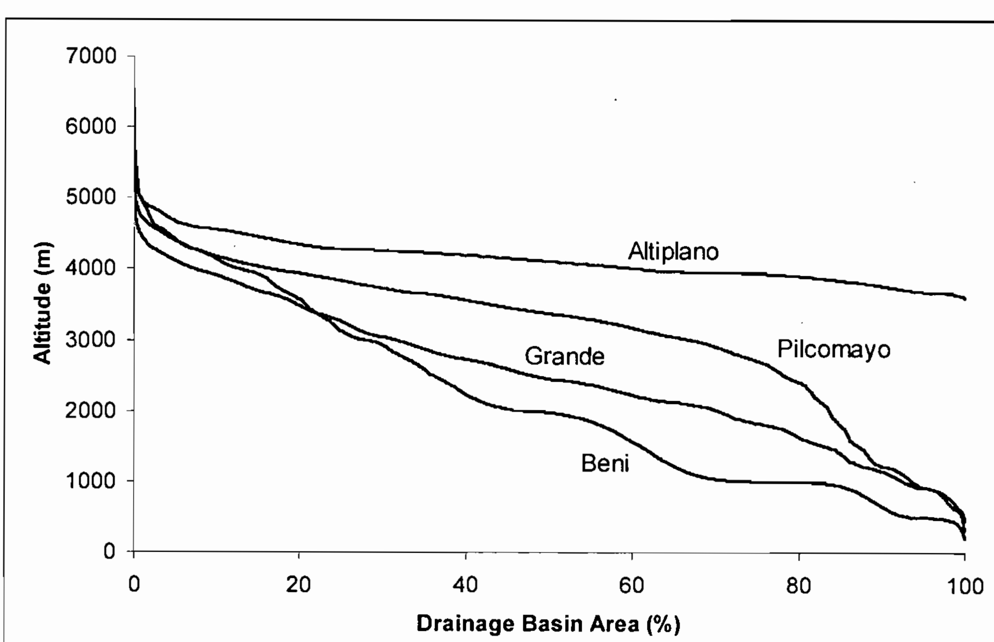

Figure 3 : Basin hypsometry

It is interesting to compare the degree of evolution of the basin with the current rate of erosion measured at the hydrological gauging stations. For that, we calculated the volume of the basin comprised between the today curve and a theoretical initial profile. Considering the current rates of erosion, the time that had been necessary to obtain the observed profiles varies from 1.4 to 2.4 MY. The results (fig. 4) show a good adjustment between current measurements (few years observation) and evolution of topography related to long scales of time.

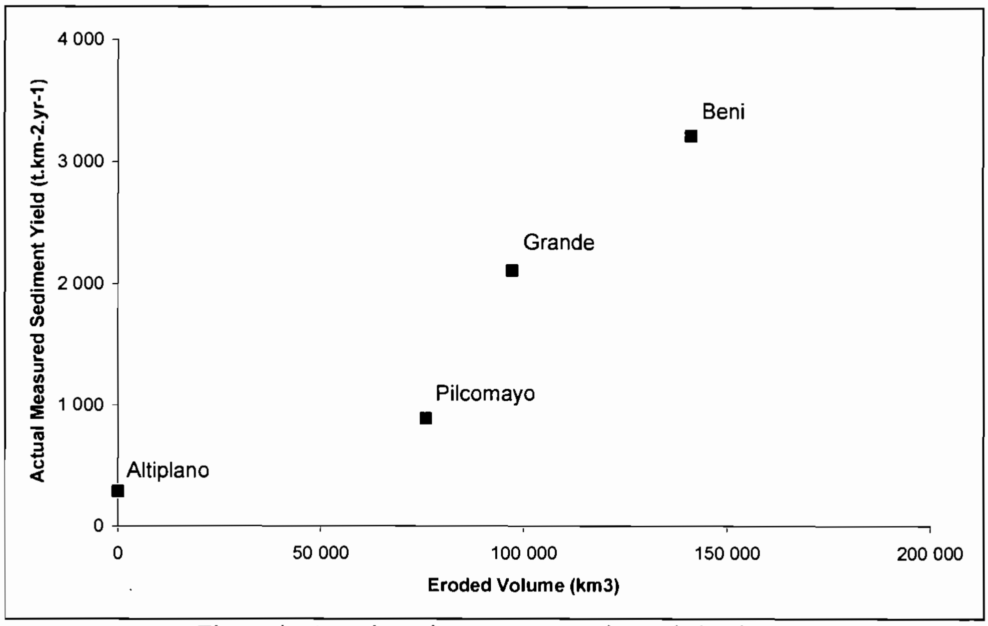

Figure 4 : Actual erosion rates vs. Basin eroded volume

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